3.15 Waveform Generator Sensitivity Analysis

Waveform is the overall form of the radio waves radiated by a pulsed radar [A.2-19]. Waveform includes the following characteristics: carrier frequency, intrapulse modulation (phase or frequency modulation within the pulse), pulse width, and pulse repetition frequency (PRF).

The radar transmitter may be considered as a single function consisting of the radar's transmission of microwave energy to the radar antenna, and having specific frequency, power, and modulation characteristics which can be exploited to maximize the radar's ability to detect and track desired targets. Since the transmitted waveform is generally not responsive to dynamic external stimuli, it is typically modeled simply as input of the emission characteristics.

Since specific measured characteristics of the transmitted waveform, power, and frequency can be input to the model, the function can be considered valid. However, the typically used transmission waveform characteristics are nominal radar transmission parameters for a given radar type. A specific radar of the given radar type will likely have transmitter characteristics which are not nominal values. Therefore, the simulated radar using nominal transmitter characteristics may not replicate a given radar's performance.

ALARM implicitly models the radar transmitter as an emitting source having waveform characteristics (i.e., pulse width, frequency, PRF, and peak power) represented by the respective input values for these parameters. These transmitter parameters are used in ALARM to simulate various radar functions.

3.15.1 Objectives and Procedures

Because of the way the Waveform Generator is implemented in ALARM, validation of this FE is unnecessary. However, sensitivity analysis must be conducted to determine the measurement accuracy required for the model input parameters associated with this FE. For this reason, only model-level sensitivity analysis is needed to characterize the requisite accuracy of the input parameters.

The objective of the sensitivity analyses of the waveform generator functional element is to determine the impact of varying radar transmitter characteristics, for a given radar type, on radar performance. The transmitter characteristics to be varied include transmitter power, pulse width, and frequency.

In each case, the measure of effectiveness used to determine sensitivity is a 5% change in normalized mean target detection range when comparing the test cases with the baseline cases.

Transmitter Power: The peak power transmitted by specific operational radars is rarely that of the nominal values assigned for the radar type. To determine the impact of using values that differ from the nominal value for peak transmitter power, the procedure is to vary the peak transmitter power by ±10% of the nominal value and analyze the effect on initial target detection range.

Pulse Width: The transmitter pulse width of a specific operational radar varies from the nominal value for the radar type. For a matched filter radar receiver, the noise bandwidth varies inversely with the pulse width. To determine the impact of using other than nominal values for the pulse width, the procedure is to vary the radar pulse width and the noise bandwidth by ±10% of their nominal values and analyze the effect on initial target detection range.

Frequency: Operational radars of a given type operate over a range of frequencies, selected to avoid cross-radar interference. The procedure for evaluating the impact of using radar frequencies other than the nominal values is to vary the radar transmitter frequency by ±10% of the nominal value and observe the effect on initial target detection range.

Table 3.15-1 identifies the specific parameters varied, and the output variables recorded, during each ALARM run.

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Table 3.15-1 ALARM Runs for Waveform Generator Sensitivity Analyses

Sensitivity Parameter	Analysis Level	Input Variable	Range of Variation	Output Variable	Test Case Description
Transmitter Power	Model	PSUBT	**200 kW** 180 kW 220 kW	SIGTOI	ALARM is run in Contour Plot mode using the indicated values for transmitter power. Initial target detection range for each flight path offset for each input value is determined.
Radar Pulse Width and Noise Bandwidth	Model	PULWID; BWMHZ	**0.25 μsec; 6.0 MHz** 0.225 μsec; 5.4 MHz 0.275 μsec; 6.6 MHz	SIGTOI	ALARM is run in Contour Plot mode using the indicated values for pulse width and noise bandwidth. Initial target detection range for each flight path offset for each input case is determined.
Frequency	Model	FREQIN	**14875 MHz** 13388 MHz 16363 MHz	SIGTOI	ALARM is run in Contour Plot mode using the indicated frequency values. Initial target detection range for each flight path offset for each input value is determined.
Note: Values in **bold** indicate baseline case.					

3.15.2 Results

Transmitter Power: As can be observed in figure 3.15-1, a plot of target detection range vs. target offset flight path as a function of transmitter power, there are small changes in target detection range as transmitter power is varied. As expected, the target detection range varies directly with the fourth root of transmitter power. As shown in table 3.15-3, for a 10% change in transmitter power, the impact of transmitter power on target detection range is insignificant (approximately 2%).

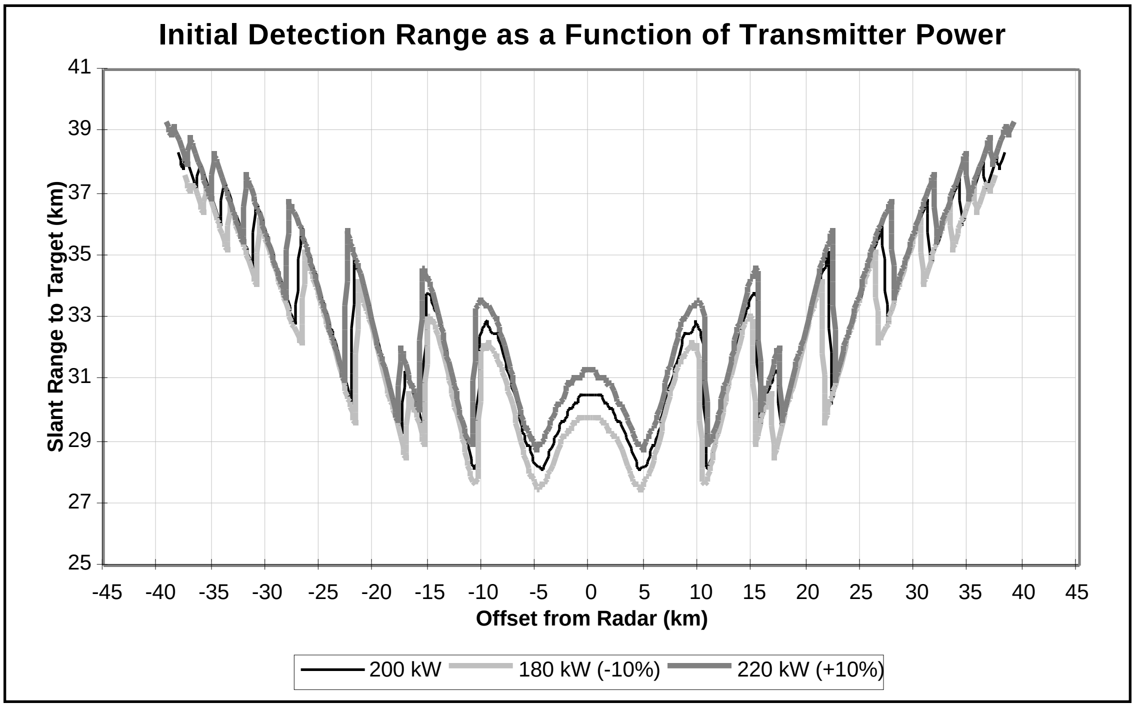

Figure 3.15-1 Initial Target Detection Range as a Function of Peak Transmitter Power

Table 3.15-2 Detection Range Variances as a Function of Peak Transmitter Power

Transmitter Power (kW)	Mean (m)	σ (m)	Normalized Mean Difference	%Change
200 (Baseline)	32.62	2.80	-	-
180 (-10%)	31.98	2.84	-0.01	–1.97
220 (+10%)	33.28	2.77	0.01	2.03

Pulse Width: As modeled in ALARM, pulse width does not directly impact target signal amplitude. However, if the pulse width of the radar is increased, the receiver matched filter bandwidth is decreased. This results in a decrease in receiver noise and hence an expected increase in initial target detection range. As can be observed in figure 3.15-2, there is a noticeable impact on target detection range for variations in pulse width. It is interesting to note that an increase in transmitter pulse width would increase the clutter signal return. This effect is masked due to MTI clutter suppression. As shown in table 3.15-3, there is an insignificant change in target detection range (less than 2%) for a 10% change in transmitter pulse width and receiver bandwidth.

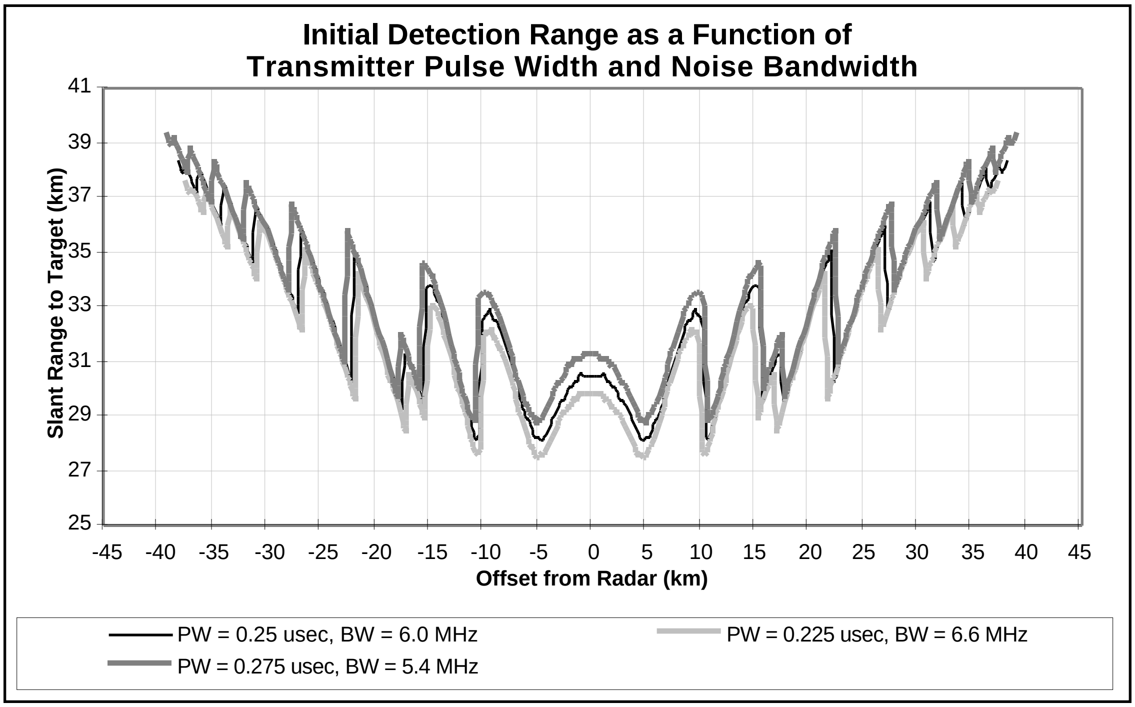

Figure 3.15-2 Initial Target Detection Range as a Function of Radar Pulse Width and Noise Bandwidth

Table 3.15-3 Detection Range Variances as a Function of Radar Pulse Width and Noise Bandwidth

Case	Mean (m)	σ (m)	Normalized Mean Difference	%Change
Pulse Width = 0.25 μsec, Noise Bandwidth = 6.0 MHz (Baseline)	32.73	2.87	-	-
Pulse Width = 0.225 μsec, Noise Bandwidth = 6.6 MHz	31.98	2.84	-0.01	–1.97
Pulse Width = 0.275 μsec, Noise Bandwidth = 5.4 MHz	33.28	2.96	0.01	1.70

Frequency: Figure 3.15-3 is a plot of maximum target detection range vs. target offset as a function of radar frequency variations. As can be observed, for a 10% reduction in radar frequency, i.e., a frequency of 13388 MHz relative to the nominal radar frequency of 14875 MHz, there is a 5 km increase in target detection range at a 0.0 km target offset. As shown in table 3.15-3, there is a 9.09% change in the mean normalized detection range for the 10% decrease in transmitter frequency.

These results are expected since the received target signal is proportional to the square of the radar wavelength. For the sensitivity analysis, both the target radar cross section and antenna gain remained constant as a function of frequency. In the “real world” both antenna gain and target cross section are variables as a function of frequency which would further impact target detection range. If the radar frequency is varied there should be a corresponding change in target RCS and antenna gain to fully account for transmitter frequency variations. In analyzing figure 3.15-3, it is interesting to note that depending on the inbound target offset, the initial target detection range differences vary both positively and negatively relative to the baseline case. This is expected since the doppler frequency increases with the radar frequency. The MTI filter response is not linear with frequency.

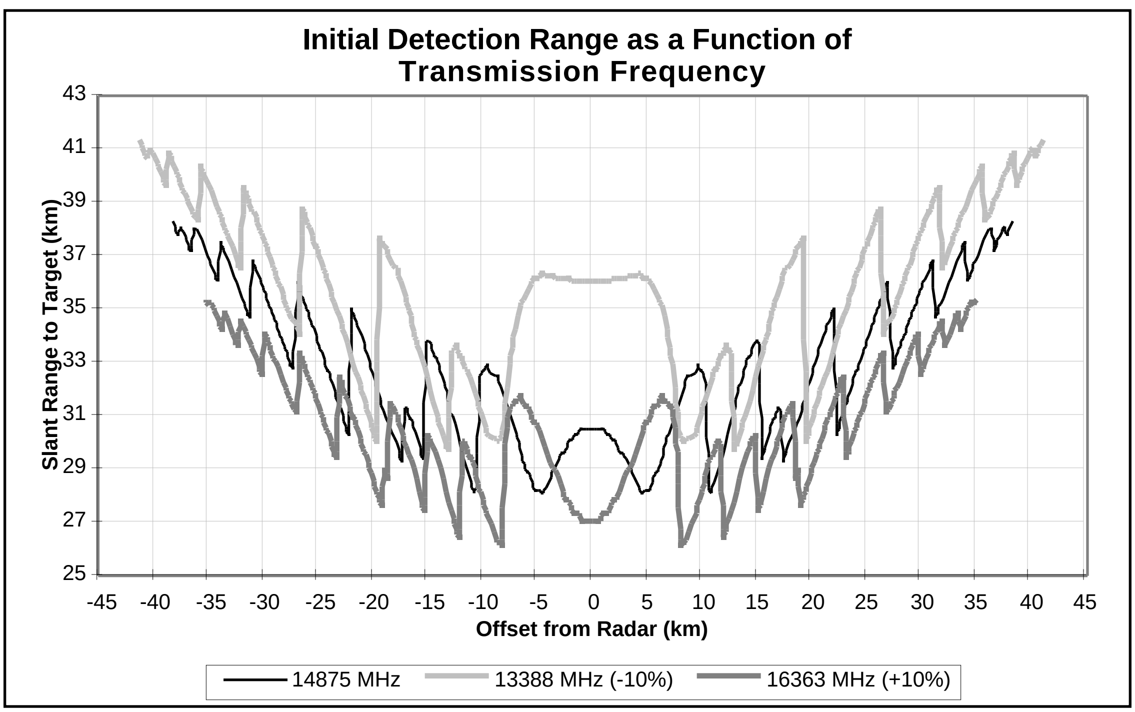

Figure 3.15-3 Initial Target Detection Range as a Function of Radar Transmission Frequency

Table 3.15-4 Detection Range Variances as a Function of Transmitter Frequency

Frequency (MHz)	Mean (m)	σ (m)	Normalized Mean Difference	%Change
14875 (Baseline)	32.73	2.87	-	-
13388	35.70	3.06	0.04	9.09
16363	30.47	2.38	-0.03	-5.67

3.15.3 Conclusions

Transmitter Power: Initial target detection range is impacted slightly by varying transmitter power. To assure accurate model target detection range predictions, the candidate radar peak pulse power should be measured to an accuracy of ±10% of the nominal value for the radar type under test.

Pulse Width: Initial target detection range is slightly impacted by changes in pulse width and receiver bandwidth. The radar pulse width and receiver bandwidth should be measured to an accuracy of ±10% of the nominal values for the radar type under test.

Frequency: Initial target detection range is impacted significantly by changes in transmission frequency. Radar transmitter frequency measurement accuracy of less than 10% of the nominal value for the radar type under test is required for validation data measurement.

The user should be aware that actual radar transmitter parameters may vary from nominal values. For tolerances of ±10%, the analyses indicate that only radar transmitter frequency has a significant impact on target detection predictions.